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Comparison of amplified spontaneous emission pulse cleaners for use in chirped pulse amplification front end lasers

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Abstract: We compare various schemes for removing amplified spontaneous emission from seed laser pulses. We focus on compact schemes that are compatible with fiber laser front end systems with pulse energies in the 10nJ-1μJ range and pulse widths in the 100fs-10ps range. Pre-pulse contrast ratios greater than 10^9 have been measured.

1. Introduction

There has been a proliferation of high energy chirped pulse amplification (CPA) systems through out the world. As energies are scaled it becomes increasingly important for these systems to have a high degree of pre-pulse contrast. Otherwise the amplified spontaneous emission (ASE) preceding the pulse can become energetic enough to interfere with or destroy the experimental target. In order to achieve high pre-pulse ASE contrast in a system with known output energy and gain, one must inject into the amplifier chain a pulse with at least the desired contrast ratio and with energy sufficient to keep the gain below a pre-determined level. The ASE power level of a system is proportional to the system gain and bandwidth and can be estimated from the following equation [1].

$$P_{ASE} = 2 n_{sp} (G-1) h \nu \Delta \nu$$

Where n_{sp} is the spontaneous photon number (usually around 1, physically representing a single photon per mode injected at the input of the amplifier chain), G is the system gain, h is Plank's constant, ν is the laser frequency and $\Delta \nu$ is the system bandwidth. High energy CPA systems can have pre-pulse requirements on the order of 10^8 to 10^{10} . This requirement flows backwards through a typical system to a requirement on the input pulse energy of at least this pre-pulse contrast. Furthermore, the equation above leads to minimum pulse energy out of the stretcher. This clean pulse energy can easily exceed 10nJ in order to meet the system requirements. Accounting for stretcher losses the required pulse energy may be in the 20nJ to 1μJ range. This is beyond the pulse energy easily achievable from a typical oscillator. The typical solution to this problem is the amplify a pulse produced by a mode locked laser either without employing CPA or by employing a minimal version of CPA (where the pulse is stretched only to a few ps and then recompressed) and then using a pulse cleaner to achieve the desired pulse contrast.

We have studied a variety of pulse cleaners suitable for use with pulses in the 10nJ-1μJ energy range and with pulse widths varying from 100fs to 10ps [2-5]. Two of these schemes involve the use of non-linear polarization rotation which has a high degree of self phase modulation (π - 3π radians minimum at the peak), which broadens the seed pulse bandwidth during the cleaning process. This may or may not be helpful from a systems standpoint. One scheme uses self phase modulation and keeps the total phase shift below 1, but involves the use of interferometer. The final scheme uses resonant saturable absorption in a semiconductor structure, which can in principle have no self phase modulation, but which can be limited in response time and has limited effective bandwidth and relatively high losses. In our poster we will provide diagrams of all of these systems and the basic equations governing their use as well as a summary table of the schemes pro and cons.

2. Experiments

We have investigated several of these schemes experimentally [2,3 and 5] and have measured prepulse contrast improvements of greater than 100 with total pre-pulse contrasts exceeding 10^9 . Our experimental set-up consists of a mode-locked fiber laser with ~ 1 nJ pulse energy, 1053nm center wavelength and 30nm of bandwidth. These pulses are stretched to 40ps in a 40m piece of PM optical fiber. They are then amplified to 200nJ by a two stage optical fiber amplifier. The resulting pulses can be recompressed to close to their transform limit by a simple and compact pair of gratings in a standard compressor geometry. These pulses were characterized with SHG FROG, a high dynamic range background free auto-correlator and a fast photodiode with calibrated neutral density filters to look at ASE 200ps ahead of the pulse. The system was shown to have a prepulse contrast of 10^6 . Application of the various pulse contrasts enhancement schemes led to an improvement of pre-pulse contrast in the range of 100-1000 using the photo-diode and neutral density filter measurement. Data from the commercial pulse cleaner [5] based on a resonant semiconductor saturable absorber is shown in the figures below.

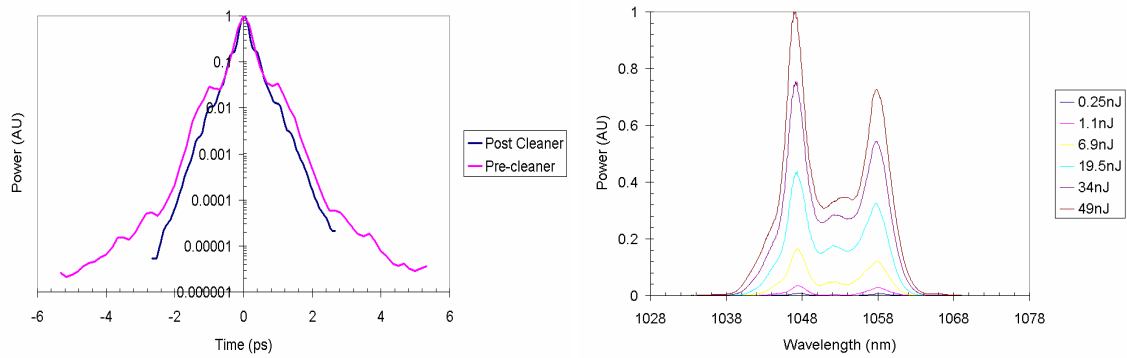


Figure 1: Left hand side: Comparison of the auto-correlation traces of the pulse before and after the pulse cleaner. Right hand side: transmitted spectra through pulse cleaner.

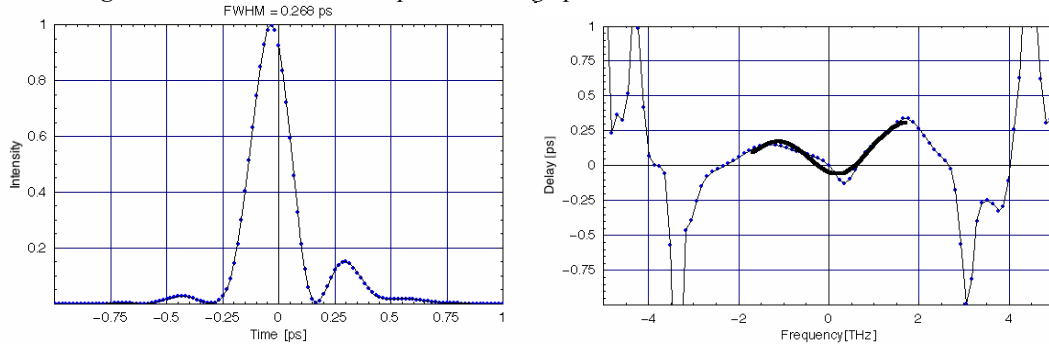


Figure 2: Right hand side: retrieved pulse from FROG measurement at output of pulse cleaner (side-lobes are a result of sharp edges on the spectra) FROG error was 0.00113. Left hand side: residual group delay within the pulse, showing good recompression post cleaning.

3. References

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